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Distribution of Salmon and Related Oceanographic Features in the North Pacific Ocean, Spring 1968

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NOTE

Until October 2, 1970, the National Marine Fisheries Service, Department of Commerce, was the Bureau of Commercial Fisheries, Department of the Interior. Throughout the body of this report, which was prepared for printing before October 2, the older term is used.

UNITED STATES DEPARTMENT OF COMMERCE
Maurice H. Stans, *Secretary*

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

NATIONAL MARINE FISHERIES SERVICE
Philip M. Roedel, *Director*

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ABSTRACT

Japanese and United States research vessels made a cooperative research cruise. Differences in distribution of salmon were examined by species, by maturity, and by age group. Sockeye salmon, *Oncorhynchus nerka*, were in the more northerly waters and pink salmon, *O. gorbuscha*, in the more southerly waters, whereas chum salmon, *O. keta*, were more widely distributed and in all waters occupied by other species. The proportion of older ages decreased from north to south; immature sockeye and chum salmon were generally restricted to the more southern waters and maturing fish to the more northern waters.

The distribution of larval fish, which at times serve as food for salmon, varied by group; Hexagrammidae were in all waters occupied by salmon whereas larvae of *Hemilepidotus* and *Bathymaster* were taken only in the northern areas and Myctophidae larvae only in the southern areas occupied by salmon.

INTRODUCTION

Each year since 1955, Japan and the United States (as members, with Canada, of the International North Pacific Fisheries Convention) have been independently investigating the distribution of salmon, *Oncorhynchus* spp., on the high seas. The purpose of the research is to determine the ocean distribution, abundance, and migration of salmon and to answer pertinent questions raised by the Commission under the provisions of the Convention. To cover more area in a single coordinated effort, Japan and the United States joined in a cooperative research cruise in spring 1968 to clarify the relation between salmon distribution and oceanographic features south of the Aleutian Islands. Japan made similar research cruises in 1967. The joint cruises are scheduled to continue in subsequent years.

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Two Japanese vessels and one United States vessel participated. The *Wakashio Maru* fished from April 30 to May 24, and the *Hokko Maru* was on fishing stations from May 9 to 24. The U.S. vessel *George B. Kelez* fished from April 18 to June 15. Figure 1 shows the fishing stations of the three vessels.

This report details fishing and oceanographic results of sampling in a wide area of the North Pacific Ocean and presents data on the relation between salmon distribution and oceanographic features.

METHODS AND EQUIPMENT

Fishing gear and oceanographic equipment varied between Japanese and United States research vessels.

Fishing Gear

Japanese research vessels used gill nets and longlines as fishing gear. The research net

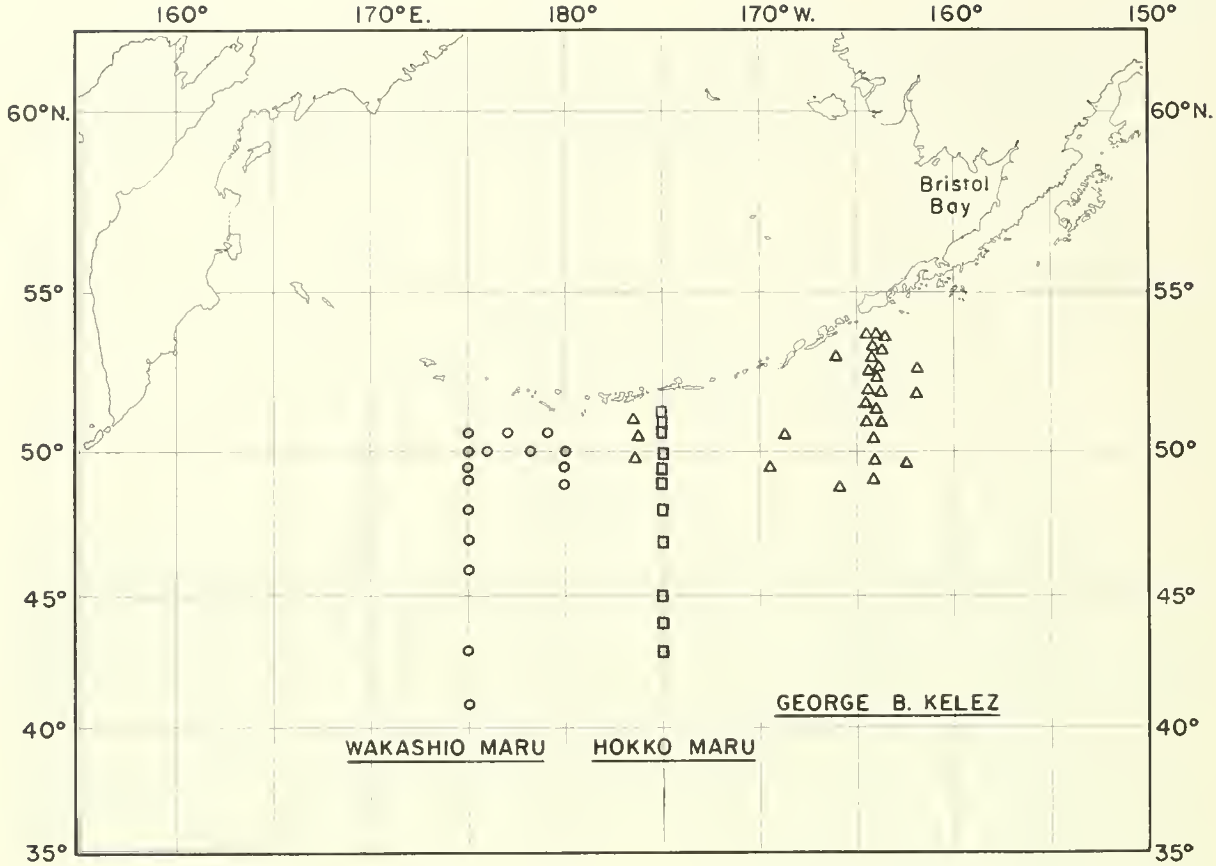

Figure 1.—Stations fished by Japanese and United States research vessels in spring 1968.

string (standard combined mesh net) consisted of 10 tans (a tan is 50 m. long) each of five mesh sizes—55, 72, 93, 121, and 157 mm. At some stations, 30 tans of a commercial mesh size for salmon (121 mm.) were added to the string. At most stations the longlines to catch fish for tagging and for comparison with gill net catches were fished along with the gill nets; either 20 or 30 hachi were set at a station (one hachi has 49 hooks).

The U.S. vessel fished 30 shackles (one shackle is about 91 m.) of gill nets of five mesh sizes—63, 82, 98, 115, and 133 mm. For experimental purposes two shackles of monofilament mesh (133 mm.) were added to the string, and on a few occasions five shackles of gear were attached below five surface nets of similar mesh sizes to sample at depth.

Oceanographic Equipment

The *Wakashio Maru* took BT (bathythermograph) readings, and the *Hokko Maru*, in addition to BT readings, measured temperatures with reversing thermometers and took salinity observations to 300 m. with a water sampler. The *George B. Kelez* used an STD (salinity, temperature, depth) instrument to obtain oceanographic data.

ENVIRONMENTAL CONDITIONS

The horizontal distribution of water temperature at 100 m. indicated a slightly different distribution of 2° C. water in 1968 compared with 1967 (fig. 2). The area of cold water was between the Transitional Domain to the south and the Alaskan Stream Area to the north. In 1968, water was not colder than 2° C. east of about long. 165° E., whereas in 1967 the cold water originating from the Western Subarctic Domain intruded well east of long. 170° E. at lat. 47° to 48° N. Temperature data near long. 170° E. were obtained from

research vessels in the landbased fishing area or from the Japanese mothership fishing fleet.

Figure 3 illustrates the vertical distribution of cold water originating from the Western Subarctic Domain. Along long. 170° E. above 200 m., the vertical range of water lower than 3° C. was less in 1968 than in 1967. Also, there was an absence of water lower than 2° C. in 1968. Figure 4 shows that no temperatures lower than 3.5° C. were observed above 125 m. and south of 50° N. along long. 175° E. in 1968. In 1968, the 5° C. isotherm was near 46° N. along long. 170° E. (fig. 3), whereas in 1967 the water at 46° N. was much colder and the 5° isotherm was 2 degrees farther south. These data show that warm water from the south extended relatively far to the north in 1968 and the cold water originating from the Western Subarctic Domain did not extend as far east in 1968 as in 1967.

The temperature and salinity structure along 175° W. and the temperature structure along long. 177°30′ W. are shown in figures 5 and 6, which illustrate the range of the Alaskan

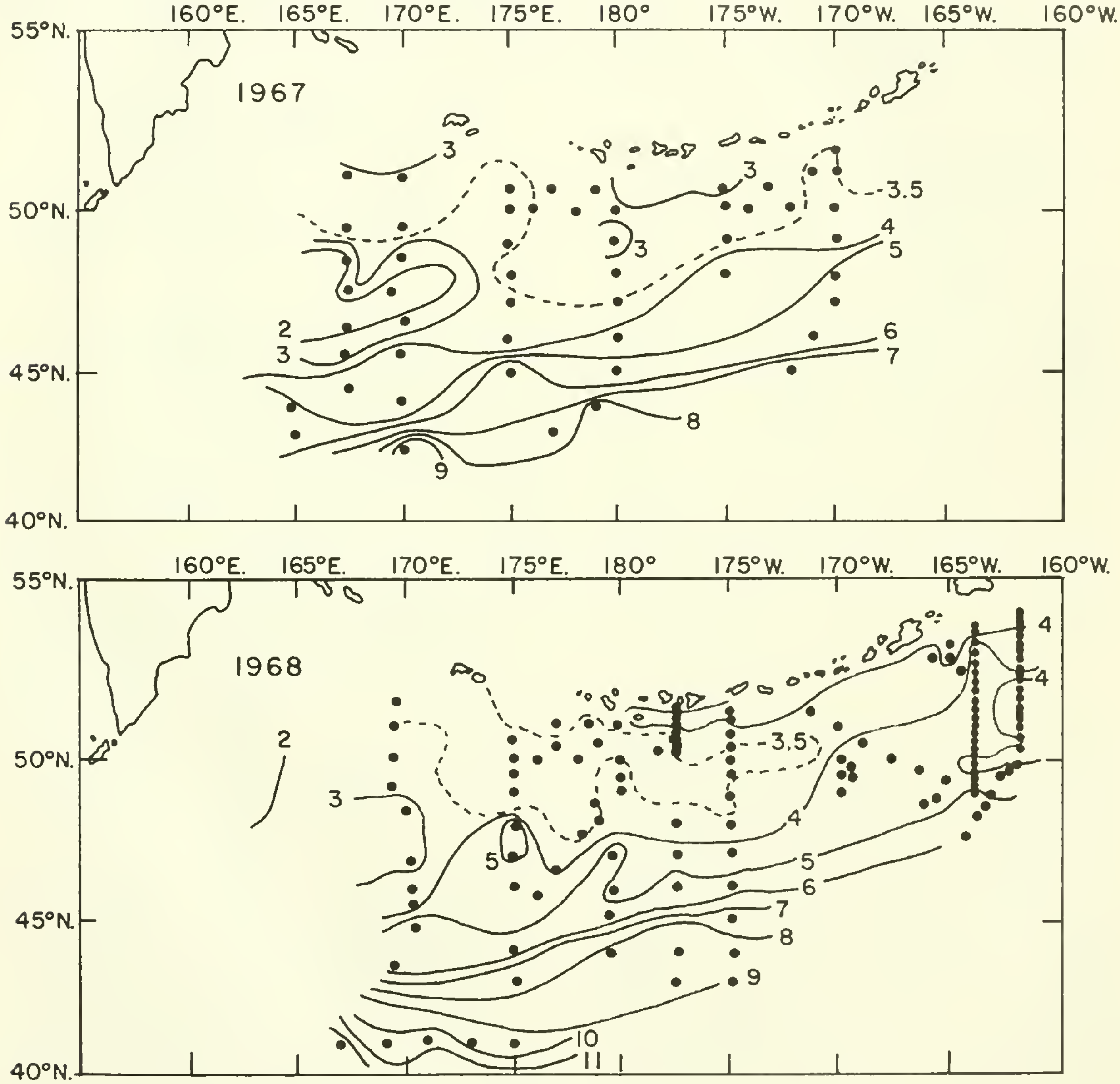

Figure 2.—Temperature (° C.) at 100-m. depth, spring 1967 and 1968.

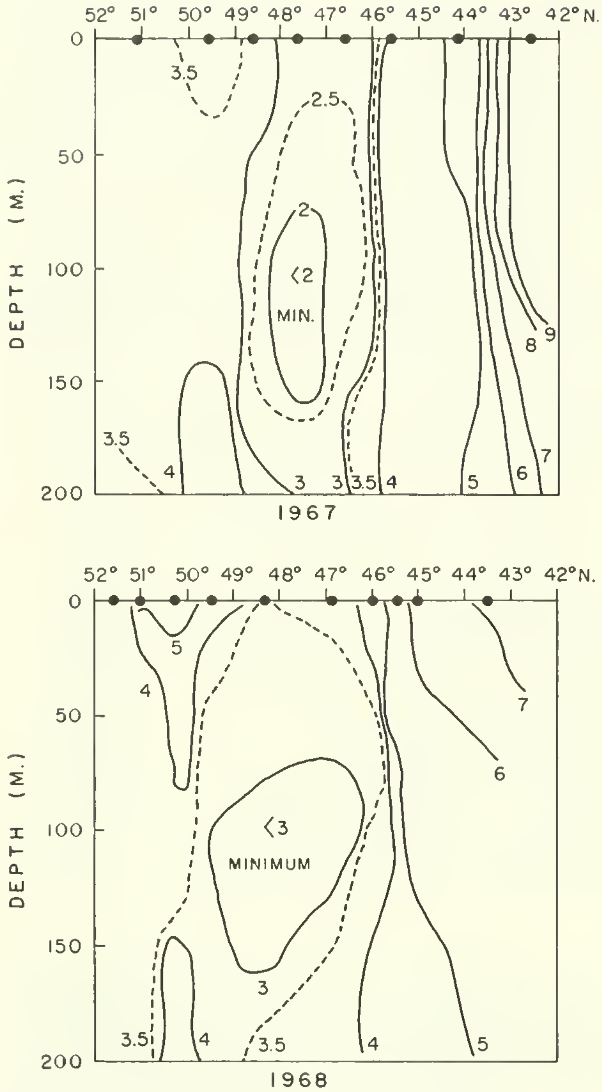

Figure 3.—Vertical sections of temperature (° C.) along long. 170° E., spring 1967 and 1968.

Stream and other water areas. Along 175° W. in May (fig. 5), salinities were lower than 32.8‰ above 100 m. from about lat. 48°30′ N. to 51°45′ N. Salinity was 32.7‰ in the upper water from lat. 51°15′ N. to 51°45′ N. The increase in salinity (33.2 and 33.3‰) in the surface layers near the islands appears to reflect the intrusion of water from the Bering Sea. The temperature structure showed a characteristic of the Alaskan Stream: Water warmer than 4° below 100 m. was north of lat. 50°30′ N. The axis of the stream was near lat. 51°20′ N. To the south of the warm water (lat. 48°30′ N. to 50° N. and from about 70 m. to 140 m.) was cold water, less than 3.5° C., which represents minimum temperatures of surface waters from the previous winter.

Along long. 177°30′ W. in May, observations of temperature to depths of 200 m., made every 9 to 19 km. between lat. 50° N. and 51°30′ N. (fig. 6) were useful in defining the precise location of the stream axis. Water warmer than 4° C. (between 100 m. and 200 m.) indicated that the axis of the stream was at lat. 51°16′ N. This position was similar to its location on long. 175° W. (51°20′ N.).

At long. 164° W. (fig. 7), the salinity and temperature structures were similar to those

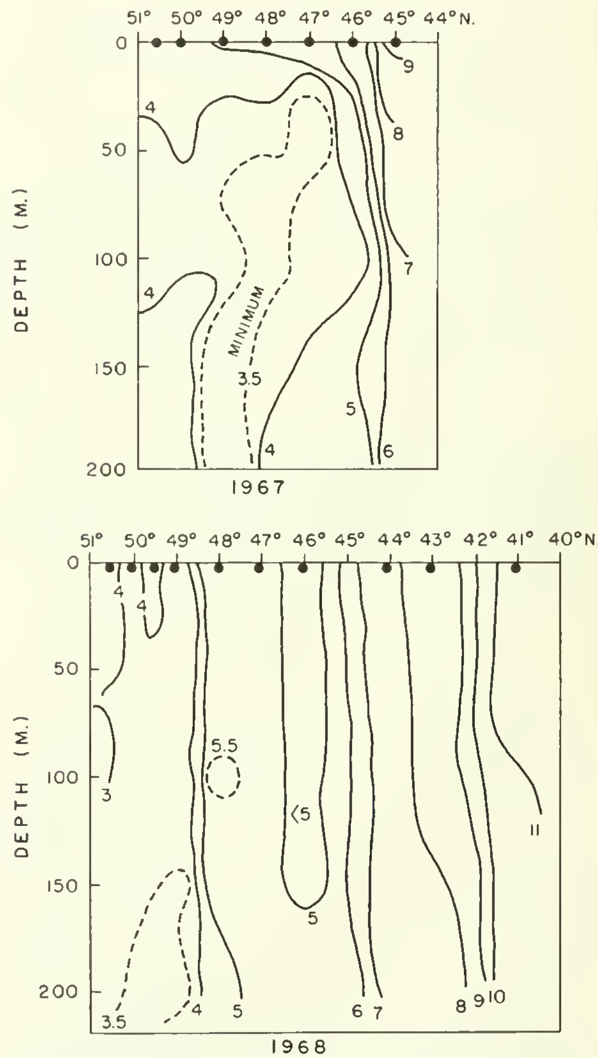

Figure 4.—Vertical sections of temperature (° C.) along long. 175° E., spring 1967 and 1968.

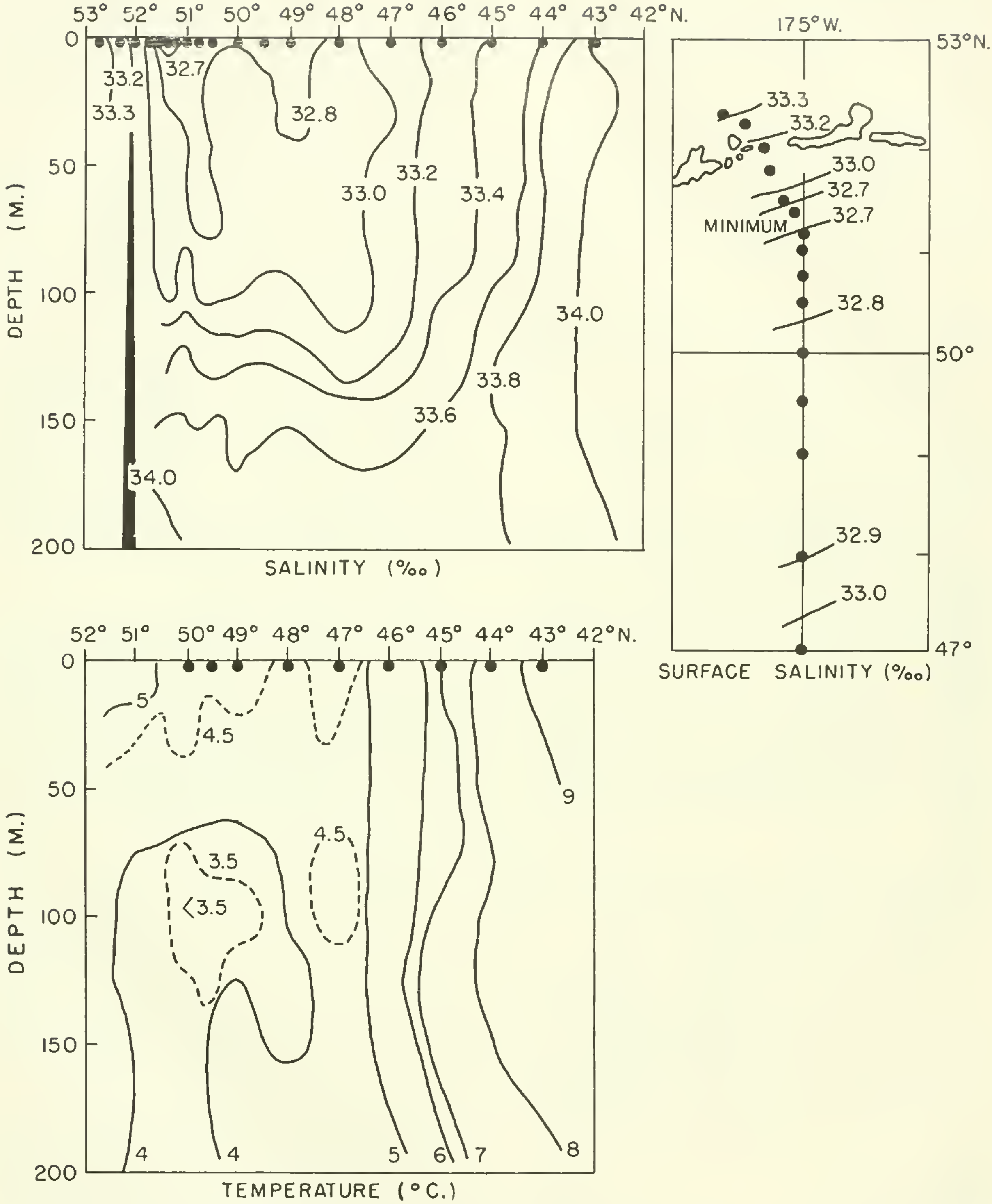

Figure 5.—Vertical sections of salinity and temperature and surface salinities along long. 175° W., spring 1968.

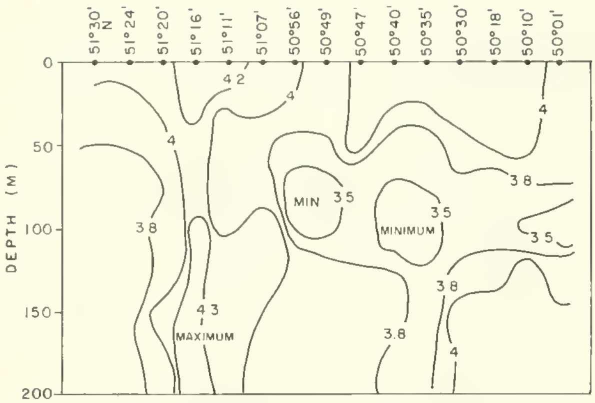

Figure 6.—Vertical sections of temperature along long. 177° 30′ W., spring 1968. (Latitudinal positions of stations are not to scale.)

at long. 175° W. From these features we concluded that the axis of the Alaskan Stream was around lat. 53°30′ N.

The preceding detailed oceanographic data were used to identify boundaries of various major oceanographic features in the North Pacific Ocean (Alaskan Stream, Ridge, Western Subarctic, and Transition Water Areas). Definitions of these Areas have been given by McAlister, Ingraham, Day, and Larrance (1970). These authors separated the Western Subarctic water into two Areas, the Oyashio Extension and Subarctic Current. Because some oceanographers question this separation, we have considered the Western Subarctic water as one Area.

DISTRIBUTION OF SALMON AS RELATED TO OCEANOGRAPHIC FEATURES

Table 1 gives salmon catches by the three research vessels by species for each set. In the following discussion and illustrations of distribution, catches have been standardized by converting them to catch per tan in which equal weight was given to each mesh size.

Sockeye Salmon

Figure 8 shows relative abundance of sockeye salmon as shown by gill net catches and the location of ocean currents and Areas. Sockeye salmon were not taken south of lat. 46° N. They extended northward to at least lat. 50°30′ N., south of the western Aleutian Islands, to lat. 51° N., south of the central Aleutians (see longline catches, table 1), and to lat. 53° N., south of the eastern Aleutians. They extended southward on this easternmost cruise track to at least lat. 49° N.

The distribution of immature sockeye salmon from north to south was relatively narrow compared with that of maturing fish and was restricted to the southern part of this range. In relation to oceanographic features, they were in the Western Subarctic and Transition or easterly moving waters.

Maturing sockeye salmon had a wider and more northerly distribution than the immatures and were in the Western Subarctic and Ridge Areas; two maturing sockeye salmon were also taken in Transition water along long. 175° E. In relation to direction of water movement, some maturing fish (particularly in the west) were in easterly moving water and some (particularly in the east) were in the weak, variable currents of the Ridge Area.

South of the central Aleutian Islands, only two small catches of maturing fish were made by gill nets, which indicated that abundance of maturing fish was low in this area compared to areas to the east and west. Longlines, however, took maturing sockeye salmon more consistently along long. 175° W. (table 1), which shows that relative abundance probably was not as low in this area as was indicated by gill net catches.

Maturing and immature sockeye salmon were also separated in the winter along long. 162° W. and 155° W. (French, Craddock, Bakkala, and Dunn, 1967)—immature fish were primarily in the western Subarctic waters and maturing fish in the Ridge Area. Distribution of maturing and immature fish along long. 164° W. in spring 1968 was similar to the distribution in winter.

Maturing sockeye salmon were farther north in early June than in May; they were concentrated in the Alaskan Stream and northern part of the Ridge Area (fig. 9). These fish were believed to be the Bristol Bay sockeye salmon on their spawning migration. The main part of this migration appeared to take place from June 1 to 10; catches were relatively much lower from June 10 to 15.

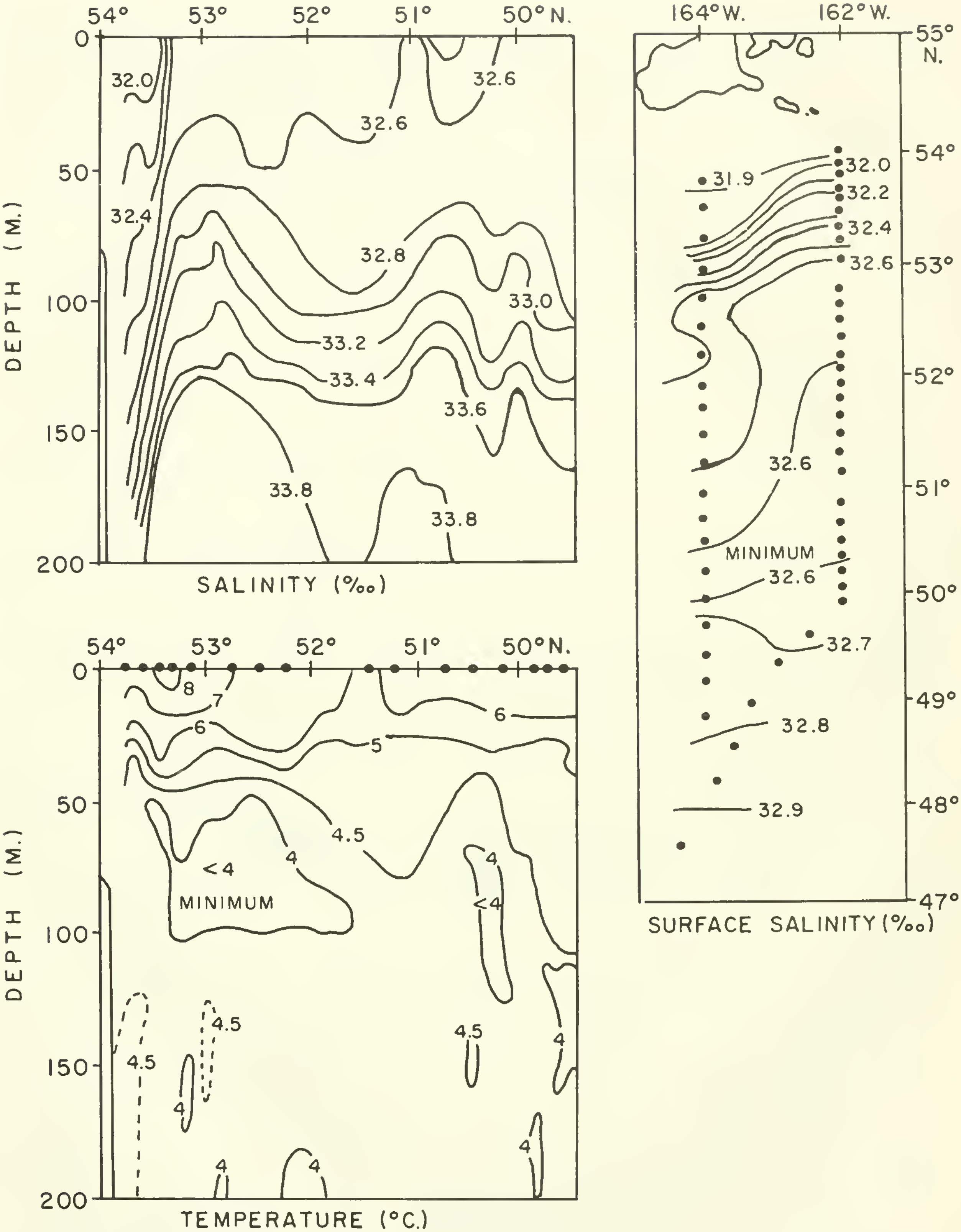

Figure 7.—Vertical sections of temperature and salinity along long. 164° W. and surface salinities along long. 164° W. and 162° W., spring 1968.

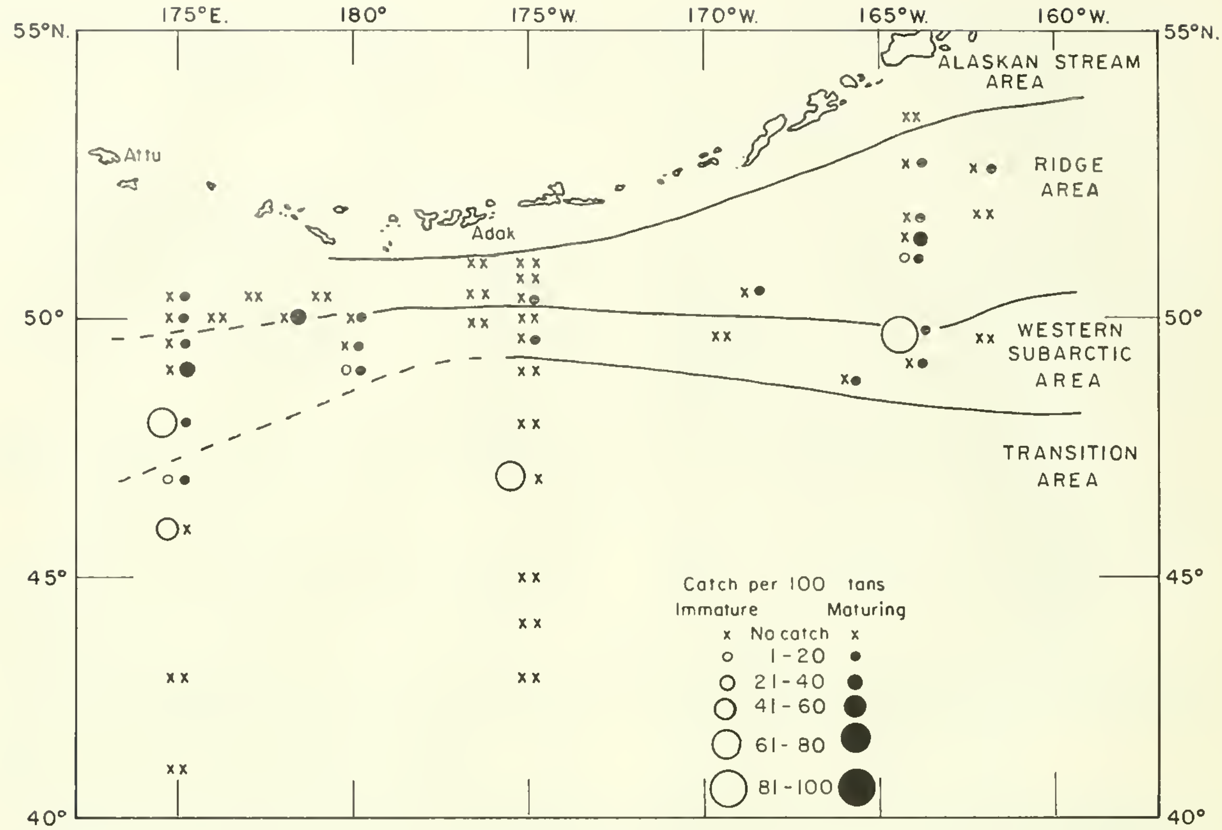

Figure 8.—Relative abundance of immature and maturing sockeye salmon as shown by gill net catches of Japanese and United States research vessels in May 1968.

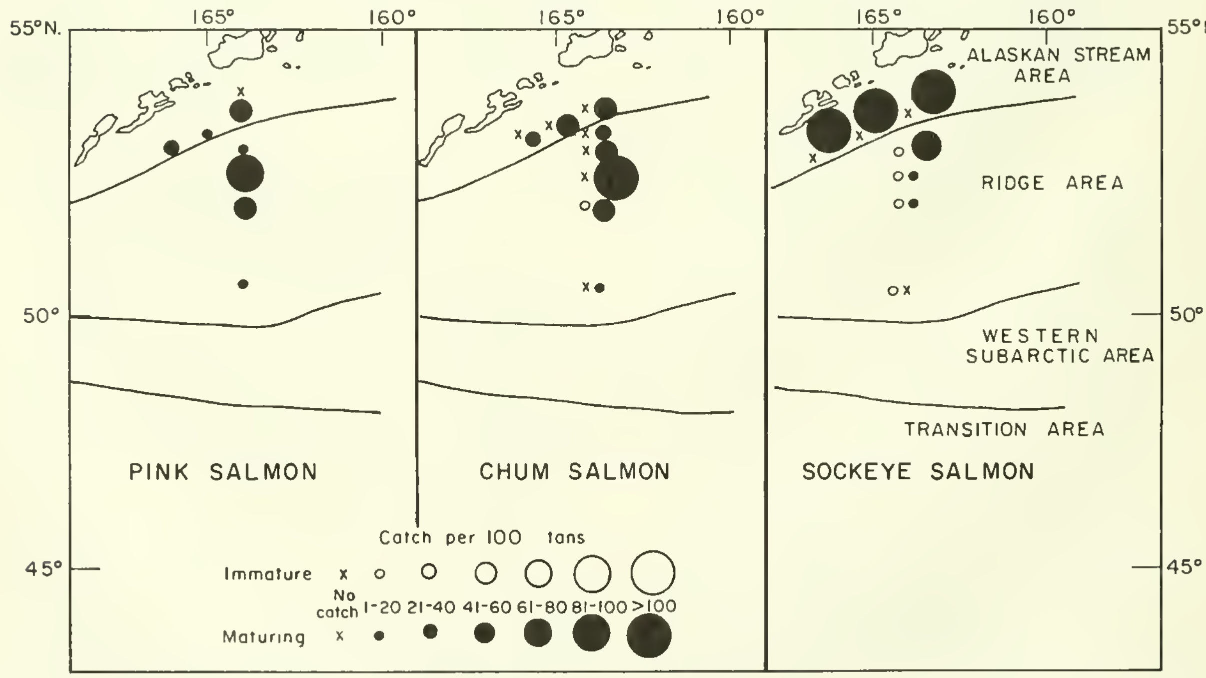

Figure 9.—Relative abundance of sockeye, chum, and pink salmon near long. 165° W. as shown by catches of the *George B. Kelez* in early June 1968.

Table 1.—Salmon catches by Japan and the United States—April, May, and June 1968

Set number[1]	Date	Position		Sea surface temp.	Gear[2]	Species of salmon					
		Lat. N.	Long.			Sockeye	Chum	Pink	Coho	Chinook	Total
Wakashio				*° C.*		*Number*					
Maru 1	4/30	41° 00	175° 00 E.	11.6	79 GT	0	4	0	0	0	4
2	5/2	42° 58	175° 02 E.	8.4	75 GT	0	17	3	3	0	23
3	5/3	44° 02	175° 00 E.	7.8	30 LL	0	27	124	1	0	152
4	5/6	46° 00	175° 02 E.	4.9	74 GT	25	30	8	0	0	63
		45° 58	175° 06 E.	4.9	30 LL	14	26	8	0	1	49
5	5/7	46° 58	175/ 00 E.	5.0	74 GT	9	25	24	0	0	58
6	5/8	47° 58	175° 03 E.	5.1	50 GT	61	20	47	0	1	129
		47° 57	175° 05 E.	5.1	30 LL	10	22	69	0	0	101
7	5/9	49° 01	175° 00 E.	3.9	50 GT	20	34	4	0	0	58
		49° 00	175° 03 E.	3.9	30 LL	42	29	1	0	0	72
8	5/10	49° 30	174° 58 E.	4.0	75 GT	8	3	0	0	0	11
9	5/16	50° 00	175° 05 E.	3.9	50 GT	0	0	0	0	0	0
		49° 58	175° 03 E.	3.9	30 LL	4	9	1	0	0	14
10	5/17	50° 28	175° 00 E.	4.2	50 GT	1	0	0	0	0	1
		50° 27	174° 58 E.	4.2	30 LL	17	26	1	0	0	44
11	5/18	49° 58	175° 55 E.	4.6	75 GT	3	0	0	0	0	3
12	5/19	50° 28	177° 00 E.	4.0	75 GT	0	0	0	0	0	0
13	5/20	50° 00	178° 00 E.	4.0	75 GT	28	7	19	0	1	55
14	5/21	50° 29	178° 58 E.	4.1	75 GT	2	2	0	0	0	4
15	5/22	50° 00	180° 00	4.8	50 GT	1	0	0	0	0	1
		49° 58	179° 58 E.	4.8	30 LL	13	4	12	0	0	29
16	5/23	49° 35	180° 00	5.1	50 GT	5	8	21	0	0	34
		49° 34	179° 59 E.	5.1	30 LL	14	13	8	0	0	35
17	5/24	49° 05	180° 00	5.6	50 GT	9	5	3	0	0	17
			Total		1027 GT	172	155	129	3	2	461
					240 LL	114	156	224	1	1	496

See footnote at end of table.

Table 1.—Salmon catches by Japan and the United States—April, May, and June 1968—Continued

Set number[1]	Date	Position		Sea surface temp.	Gear[2]	Species of salmon					
		Lat. N.	Long.			Sockeye	Chum	Pink	Coho	Chinook	Total
Hokko				° *C.*		— — —	— — —	— — *Number*	— — —	— — —	— — —
Maru 1	5/9	42° 59	175° 00 W.	9.4	77 GT	0	10	17	19	0	46
2	5/10	44° 04	175° 01 W.	8.6	84 GT	0	52	53	18	1	124
3	5/11	45° 01	175° 00 W.	7.0	50 GT	0	2	10	1	0	13
		45° 06	175° 00 W.	7.0	30 LL	0	105	41	0	0	146
4	5/12	45° 57	175° 03 W.	5.6	30 LL	2	16	22	0	0	40
5	5/13	47° 09	175° 06 W.	4.8	30 LL	4	6	15	0	0	25
6	5/15	47° 00	174° 59 W.	4.8	50 GT	31	10	16	0	0	57
		47° 00	174° 59 W.	4.8	20 LL	45	10	13	0	0	68
7	5/16	48° 01	175° 00 W.	4.4	50 GT	0	0	0	0	0	0
		48° 01	175° 03 W.	4.4	28 LL	4	13	31	0	0	48
8	5/17	48° 58	175° 01 W.	4.7	50 GT	0	0	0	0	0	0
		48° 56	175° 05 W.	4.7	30 LL	14	4	17	0	0	35
9	5/18	49° 30	175° 00 W.	4.5	47 GT	2	5	2	0	0	9
		49° 27	175° 00 W.	4.5	29 LL	5	1	3	0	0	9
10	5/20	50° 01	174° 59 W.	4.7.	47 GT	0	0	0	0	0	0
		49° 58	174° 59 W.	4.7	30 LL	4	6	2	0	0	12
11	5/21	50° 31	174° 59 W.	4.7	50 GT	1	0	0	0	0	1
		50° 32	175° 03 W.	4.7	30 LL	0	0	0	0	0	0
12	5/22	50° 45	175° 00 W.	5.1	50 GT	0	0	0	0	0	0
		50° 46	175° 03 W.	5.1	30 LL	13	1	2	0	0	16
13	5/23	51° 02	175° 00 W.	5.3	50 GT	0	0	0	0	0	0
		50° 58	175° 03 W.	5.3	30 LL	8	14	6	0	0	28
14	5/24	51° 14	174° 59 W.	5.0	30 LL	11	28	19	0	0	58
			Total		605 GT	34	79	98	38	1	250
					347 LL	110	204	171	0	0	485

See footnote at end of table.

Table 1.—Salmon catches by Japan and the United States—April, May, and June 1968—Continued

Set number[1]	Date	Position		Sea surface temp.	Gear[2]	Species of salmon					
		Lat. N.	Long.			Sockeye	Chum	Pink	Coho	Chinook	Total
				° C.		Number					
George B. Kelez 1	4/18	52° 40	162° 00 W.	4.0	42 GS	20	1	0	0	0	21
2	4/19	51° 53	162° 00 W.	3.8	42 GS	8	2	0	0	0	10
3	4/21	49° 43	162° 22 W.	4.2	40 GS	18	0	0	0	0	18
4	4/25	49° 32	169° 25 W.	4.5	42 GS	1	0	3	0	0	4
5	4/27	49° 46	176° 29 W.	3.6	42 GS	0	0	0	0	0	0
6	4/28	50° 31	176° 08 W.	4.0	36 GS	7	0	0	0	0	7
7	4/29	51° 00	176° 25 W.	4.1	42 GS	0	0	0	0	0	0
8	5/9	48° 47	166° 06 W.	4.8	42 GS	11	15	5	0	0	31
9	5/11	49° 18	164° 11 W.	4.9	25 GS	7	16	3	0	0	26
10	5/13	51° 00	164° 00 W.	4.5	27 GS	6	15	3	0	0	24
11	5/14	51° 45	164° 00 W.	4.5	27 GS	5	2	0	0	0	7
12	5/15	52° 40	164° 00 W.	4.3	27 GS	6	4	1	0	0	11
13	5/16	53° 31	164° 02 W.	4.5	27 GS	0	12	0	0	0	12
14	5/19	53° 37	164° 03 W.	5.1	17 GS	0	19	2	0	0	21
15	5/20	52° 45	164° 00 W.	5.4	27 GS	15	5	2	0	0	22
16	5/21	51° 30	164° 00 W.	5.2	27 GS	13	13	8	0	0	34
17	5/28	50° 25	168° 43 W.	6.0	27 GS	8	26	24	0	0	58
18	5/30	49° 45	164° 00 W.	6.7	27 GS	40	23	48	0	0	111
19	5/31	50° 59	164° 01 W.	6.4	27 GS	15	34	22	0	0	71
20	6/3	52° 58	164° 00 W.	7.1	27 GS	73	31	6	0	0	110
21	6/4	52° 03	164° 04 W.	6.5	27 GS	15	27	29	0	0	71
22	6/5	53° 30	164° 00 W.	8.2	27 GS	134	97	52	0	0	283
23	6/6	53° 42	163° 59 W.	7.2	17 GS	0	1	0	0	0	1
24	6/7	52° 58	166° 01 W.	7.3	17 GS	166	11	7	0	0	184
25	6/10	53° 15	164° 50 W.	8.4	17 GS	253	32	5	0	0	290
26	6/11	52° 30	163° 58 W.	7.1	32 GS	24	61	52	0	0	137
27	6/13	50° 32	164° 00 W.	7.3	27 GS	3	3	3	0	0	9
28	6/14	52° 03	164° 00 W.	6.3	27 GS	15	47	13	0	0	75
29	6/15	53° 20	164° 00 W.	7.0	17 GS	14	14	4	0	0	32
			Total		848 GS	877	511	292	0	0	1,680

[1] Sets 1-8 of *George B. Kelez* included deep net panels.

[2] GT = Number of tans of gill nets
GS = Number of shackles of gill nets
LL = Number of hachi of longlines

Immature fish also appeared to move northward in early June. They were throughout the Ridge Area although catches were small. It is known that they inhabit the Ridge Area abundantly in the summer.

Catches gave no evidence of a major migration of maturing Bristol Bay fish south of the central Aleutian Islands in spring 1968. Support for this conclusion was based on: (1) the low relative abundance of sockeye salmon along long. 175° W., which shows that Bristol Bay fish had not reached this area by late May, and (2) the appearance in early June of migrating Bristol Bay fish in the western Gulf of Alaska—too far east to allow them to migrate westward past the central Aleutian Islands to western passes and still reach Bristol Bay in the normal time period (early July). Migrations of salmon may vary with the flow of the Alaskan Stream; we will continue to investigate this hypothesis in future studies.

Japanese research vessels also fished in the North Pacific Ocean in April and May 1967—see figure 10 for comparison of the 1967 and 1968 catches. Sockeye salmon appeared to be more abundant in 1967 than in 1968. Cruises were generally different in the 2 years, but the distribution of sockeye salmon appeared to be similar for those areas fished in 1967 and 1968; most of the fish were between lat. 45° N. and 50° N. The southern limit of distribution seemed to be farther north in 1968 than in 1967,

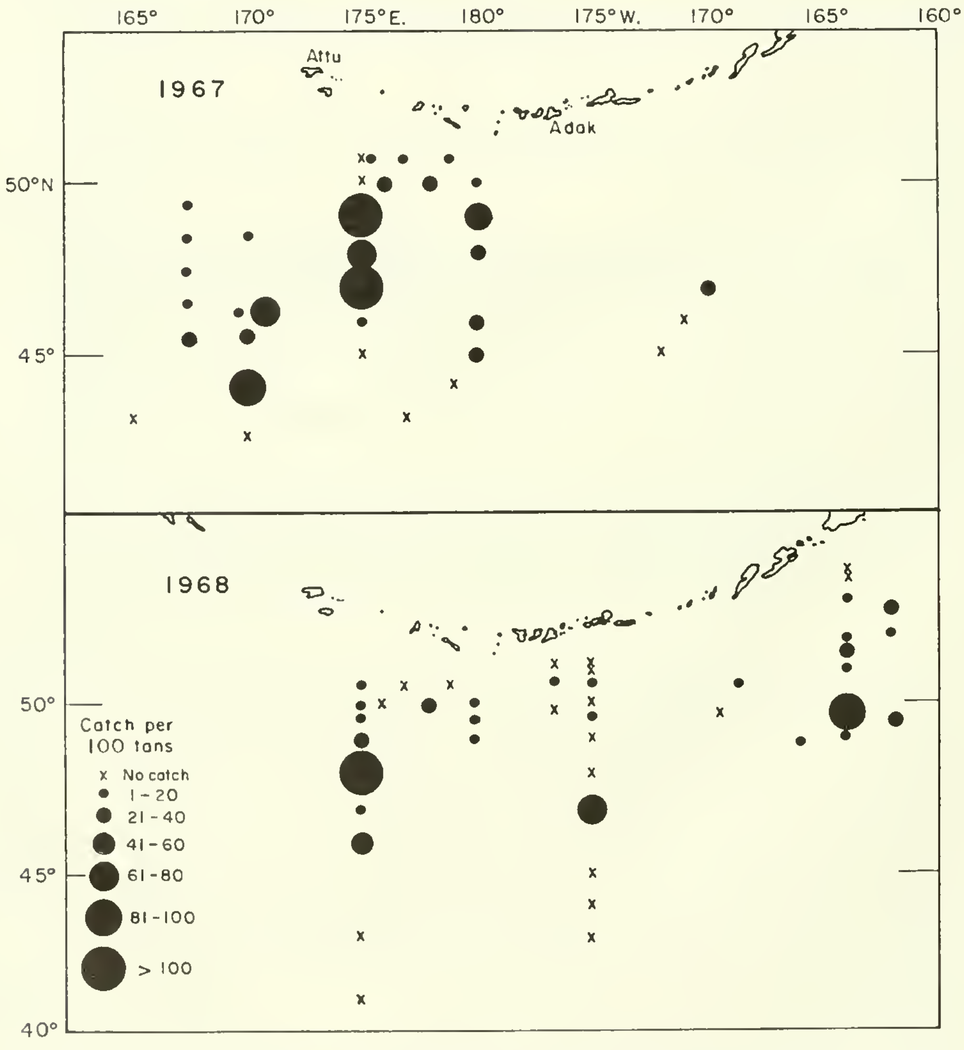

Figure 10.—Relative abundance of sockeye salmon (immature and maturing) in April and May 1967 and 1968.

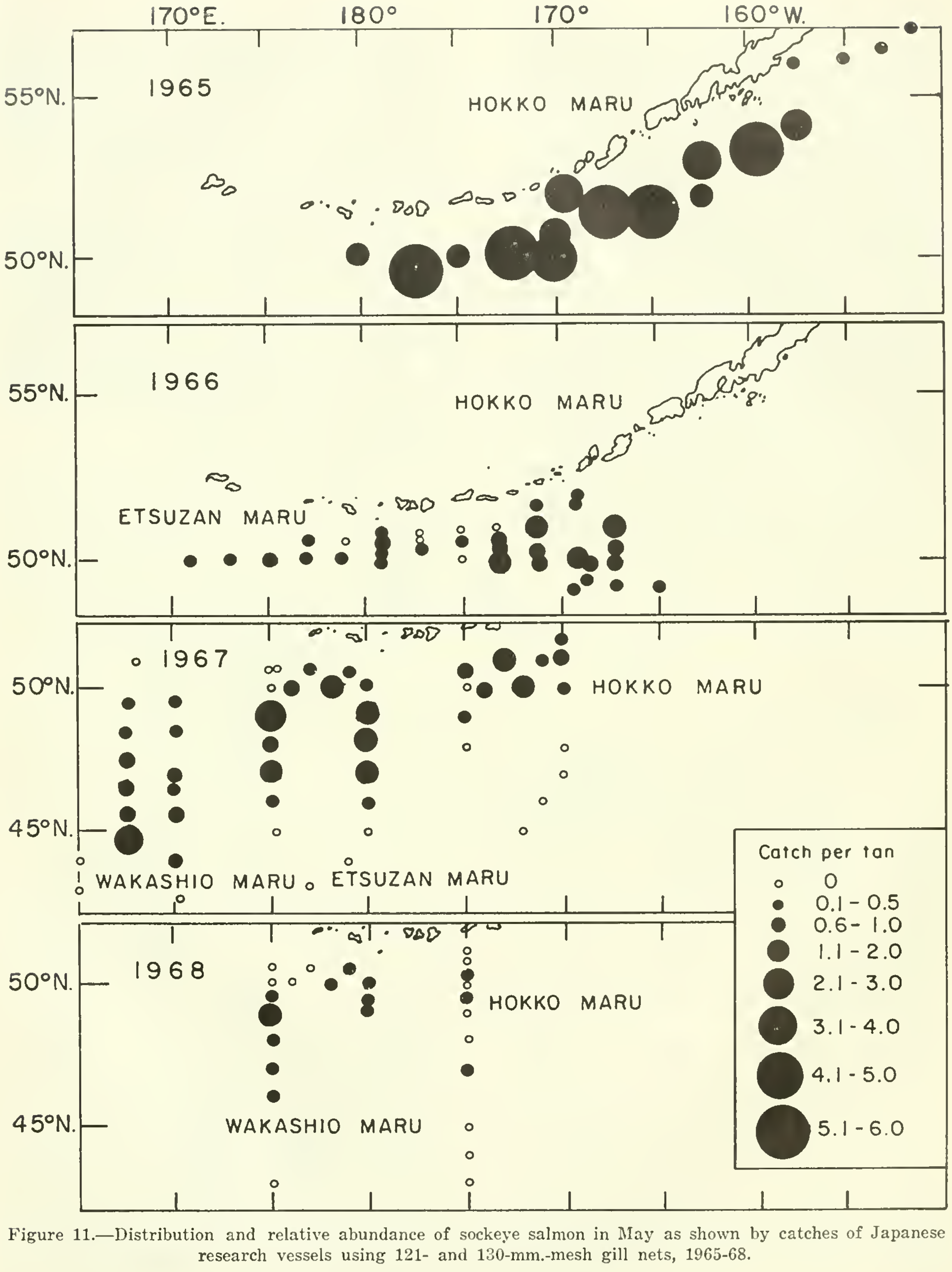

Figure 11.—Distribution and relative abundance of sockeye salmon in May as shown by catches of Japanese research vessels using 121- and 130-mm.-mesh gill nets, 1965-68.

and this shift may have been caused by the warm water (5° C. at 100 m.) being relatively farther north in 1968 than in 1967 (see section on environmental conditions).

Additional information on the relative abundance of sockeye salmon in the spring as shown by commercial mesh sizes (121- and 130-mm. mesh) has been obtained by Japanese research cruises since 1965 (fig. 11). These data show that abundance of sockeye salmon was greatest in 1965, reduced in 1966 and 1967, and lowest in 1968. The high abundance in 1965 reflects the large return of sockeye salmon (over 60 million fish) to Bristol Bay that year.

Another feature of the distribution of sockeye salmon (noted from data of 1967 in fig. 11) was an apparent northward shift in main concentrations of fish from west to east. In this season, fish were most concentrated from about lat. 45° N. to 48° N. near long. 170° E., from about lat. 47° N. to 50° N. between long. 175° E. and 180°, and from about lat. 50° N. to 51° N. between long. 175° W. and 170° W.

Chum Salmon

Chum salmon were widely distributed from north to south, extending farther south than sockeye salmon on the two western cruise tracks (fig. 12). To the east, on long. 164° W., they were taken from about lat. 49° N. to lat. 54° N., the limits of fishing.

Immature chum salmon in May, like sockeye salmon, were in the southern part of this range, but maturing chums, unlike sockeye salmon, extended as far south as the immatures. Maturing chum salmon were in all water Areas, but south of the central and western Aleutian Islands they appeared to be mainly restricted to the Western Subarctic and Transition waters. Immatures were mainly restricted to the Transition water.

In early June, south of the eastern Aleutian Islands, an increase in the abundance of maturing chum salmon indicated a migration of this species through the area at the same time as the migration of sockeye salmon (fig. 9).

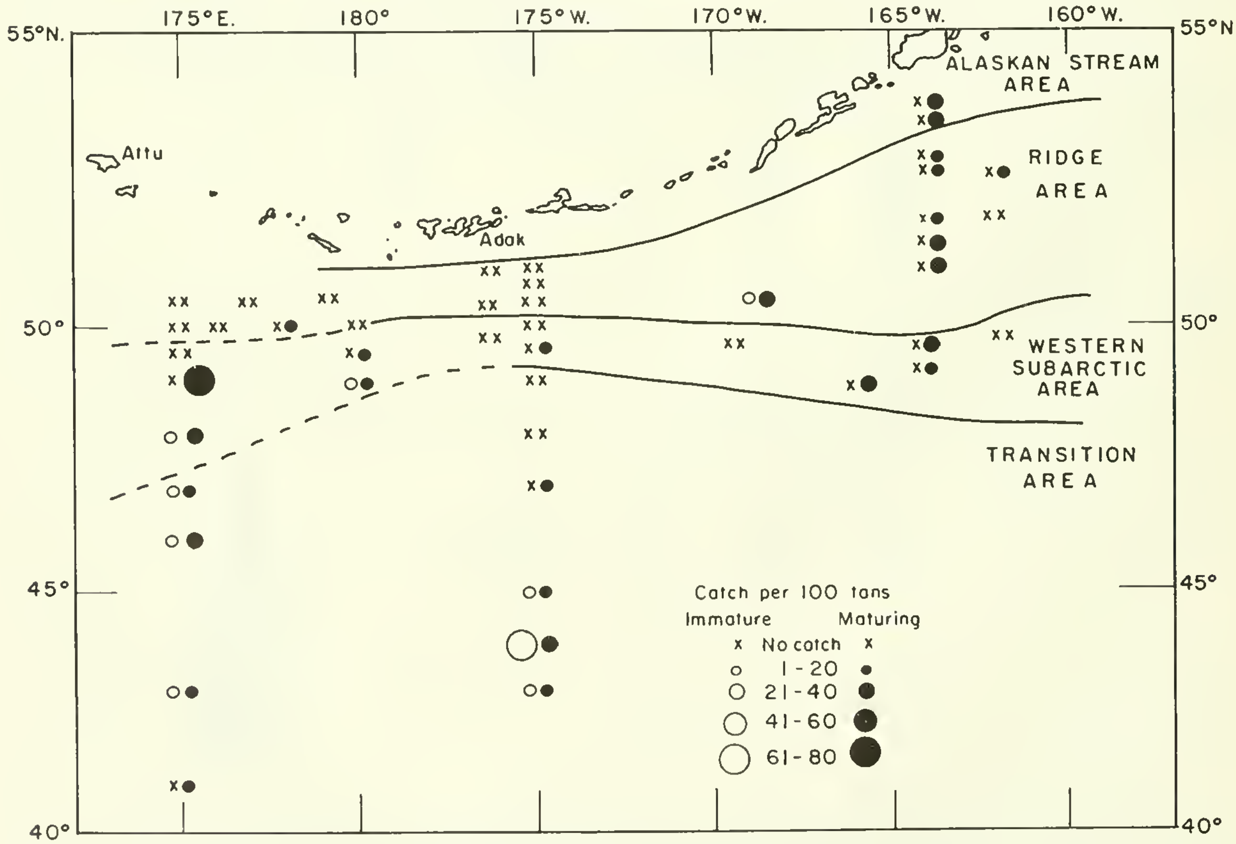

Figure 12.—Relative abundance of immature and maturing chum salmon as shown by gill net catches of Japanese and United States research vessels in May 1968.

The chum salmon migration was also in the more northerly waters, north of lat. 52° N. in the northern part of the Ridge and Alaskan Stream Areas.

Catches of chum salmon by Japanese research vessels in 1967 and by Japanese and United States vessels in 1968 (fig. 13) indicate that abundance was greater in 1967 than in 1968; the 1967 data show that main concentrations were between lat. 45° N. and 50° N. The largest catches of sockeye salmon were made at the same latitudes, and this indicated extensive intermingling between the two species in spring 1967. Intermingling was also evident from data in 1968.

Pink Salmon

The distribution of pink salmon was similar to that of chum salmon on the three 1968 cruise tracks (fig. 14). They were taken only south of lat. 50° N. by gill nets on the two westernmost cruise tracks, but some were taken north of this latitude by longlines. On the eastern cruise track they were taken from about lat. 49° N. to lat. 54° N. Main concentrations of pink salmon appeared to be south of main concentrations of chum and sockeye salmon; this relation was also evident from research cruises in 1967 (fig. 15). Main concentrations were centered near lat. 45° N. in the areas fished. Pink salmon were taken in all water

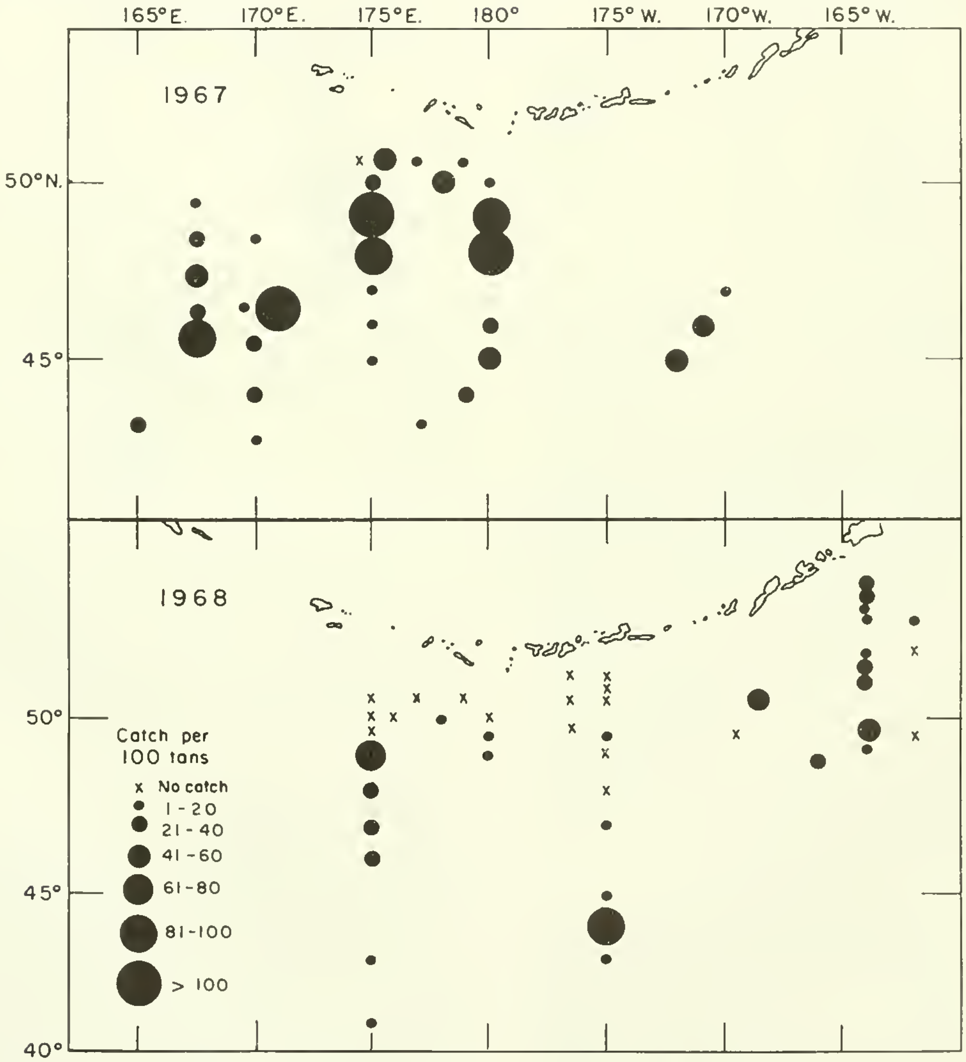

Figure 13.—Relative abundance of chum salmon (immatures and maturing) in April and May 1967 and 1968.

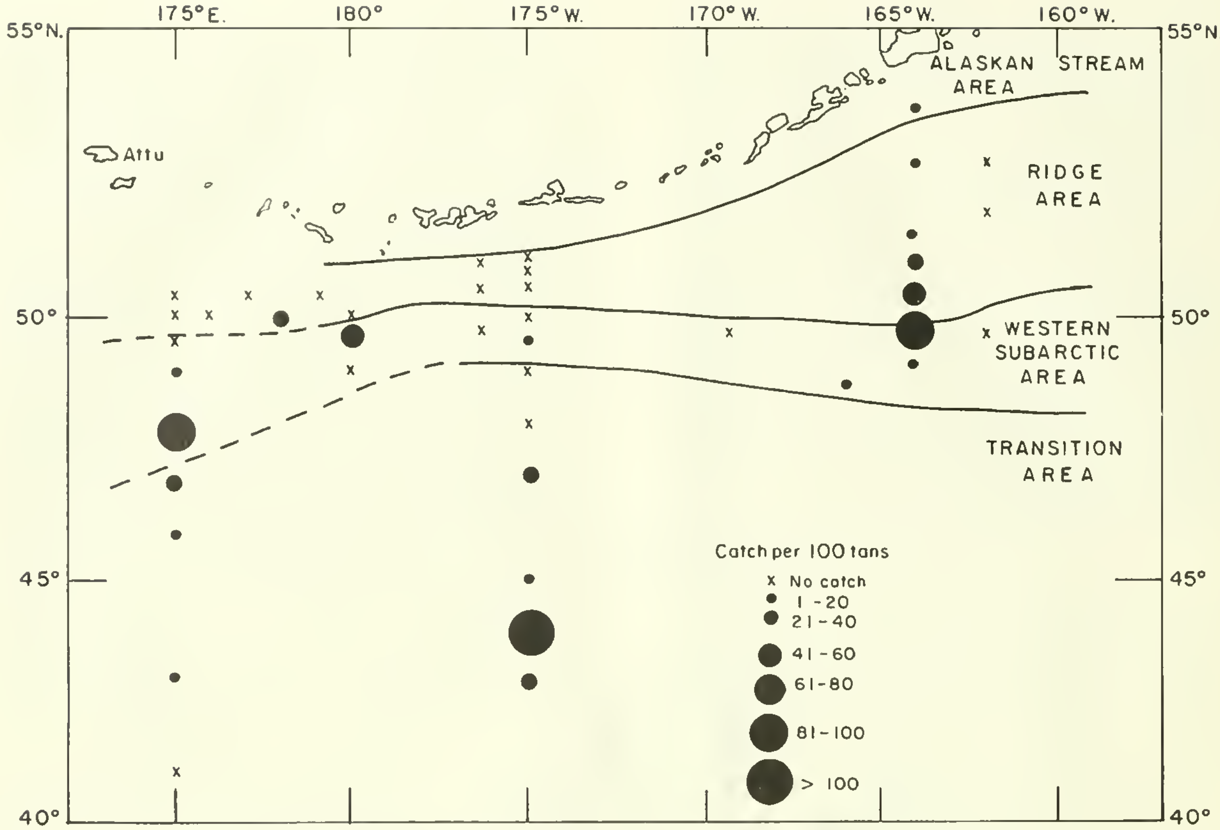

Figure 14.—Relative abundance of maturing pink salmon as shown by gill net catches of Japanese and United States research vessels in May 1968.

Areas; they were concentrated in the Western Subarctic and Transition waters south of the western and central Aleutian Islands and appeared to be most abundant in the Western Subarctic and Ridge Areas south of the eastern Aleutian Islands (fig. 14). The lack of fishing in the Transition waters along the easternmost cruise track makes this conclusion uncertain, however.

Much like the sockeye and chum salmon, pink salmon were found in more northerly waters in early June near long. 165° W. They were in the Ridge and Alaskan Stream, apparently migrating to spawning streams (fig. 9).

Coho and Chinook Salmon

Coho and chinook salmon were caught in much smaller numbers than were the other species of salmon. The *George B. Kelez* took none in waters north of lat. 48° N., whereas the *Hokko Maru* took only 38 coho and 1 chinook salmon, and the *Wakashio Maru*, 4 coho and 3 chinook (table 1). All coho were taken from lat. 45° N. and southward in Transition water.

AGE AND SIZE OF SALMON

On each cruise track the age compositions and lengths of salmon were examined to illustrate differences or similarities between areas for various species.

Sockeye Salmon

Catches by research vessels in May indicate that age composition of maturing sockeye salmon changed with latitude (table 2). Age .3 fish predominated at the more northern latitudes and age .2 fish at the more southern latitudes. When the data were combined for all latitudes the greatest proportion of the catches consisted of age .2 fish; this proportion was slightly higher (62.5 percent) near long.

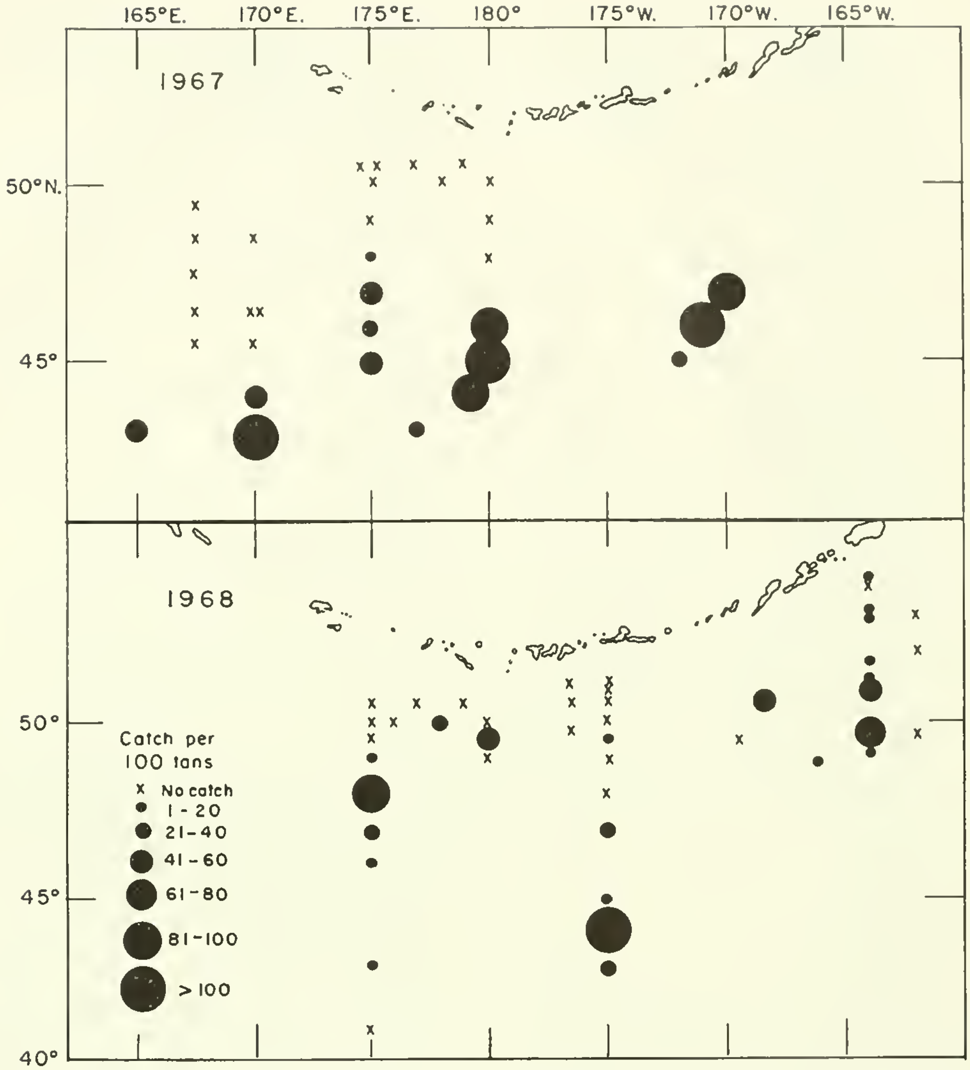

Figure 15.—Relative abundance of maturing pink salmon in April and May 1967 and 1968.

165° W. than on long. 175° E. to 180° (55.2 percent).

The age composition of the Bristol Bay fish migrating past long. 164° W. in early June was similar to that of fish in this area in May. Catches indicated that the percentage of age .2 fish increased slightly from 62.5 percent in May to 65.3 percent for migrating fish in June. These figures compare closely to the age composition of the total inshore run of sockeye salmon to Bristol Bay in 1968, which was 63.6 percent age .2 fish.

Longline catches also indicated a shift to a higher proportion of younger maturing fish from north to south (table 2). The fact that longlines are selective for larger fish is supported by catches along the cruise track of the *Wakashio Maru*: age .3 fish contributed 39.7 percent of the maturing fish caught in gill nets and 53.6 percent of those caught by longline.

A shift to younger ages at more southern latitudes was not apparent for immature fish in May; a high percentage taken on the two easternmost cruise tracks were age .2 (100 and 91 percent), but only 56 percent were age .2 in catches along long. 175° E. to 180°. In June along long. 164° W., the availability of age .1 fish increased and made up 37.5 percent of the catches.

Figure 16 shows mean fork lengths and ranges in length by maturity stage, age, sex, and location. The small number of fish in

Table 2.—Percentage age composition of immature and maturing sockeye salmon on the three cruise tracks—April and May 1968

Maturity gear and latitude	Age (winters at sea)														Sample size		
	175° E.-180°					175° W.				166° W.-164° W.							
	.1	.2	.3	.4	.5	.1	.2	.3	.4	.1	.2	.3	.4		175° E.-180°	175° W.	166° W.-164° W.
	Percent					*Percent*				*Percent*					*Number*		
Maturing:																	
Gill net:																	
52°00′ — 53°59′ N.	—	—	—	—	—	—	—	—	—	0.0	25.0	75.0	0.0		—	—	21
50°00′ — 51°59′ N.	.0	43.8	56.2	0.0	—	—	—	—	—	.0	69.5	30.5	.0		16	0	44
48°00′ — 49°59′ N.	3.0	51.5	42.4	.0	3.0	—	—	—	—	.0	94.1	5.9	.0		33	0	17
46°00′ — 47°59′ N.	11.1	88.9	.0	.0	.0	—	—	—	—	—	—	—	—		9	0	—
Total	3.4	55.2	39.7	.0	1.7	—	—	—	—	.0	62.5	37.5	.0		58	0	82
Longline:																	
50°00′ — 51°59′ N.	.0	16.7	83.3	.0	.0	0.0	25.8	74.2	0.0	—	—	—	—		12	31	—
48°00′ — 49°59′ N.	.0	54.5	45.5	.0	.0	.0	33.3	66.7	.0	—	—	—	—		44	24	—
46°00′ — 47°59′ N.	—	—	—	—	—	.0	100.0	.0	.0	—	—	—	—		0	1	—
44°00′ — 45°59′ N.	—	—	—	—	—	—	—	—	—	—	—	—	—		0	0	—
Total	.0	46.4	53.6	.0	.0	.0	30.4	69.6	--	—	—	—	—		56	56	—
Immature:																	
Gill net:																	
50°00′ — 51°59′ N.	—	—	—	—	—	—	—	—	—	30.8	69.2	0.0	.0		0	0	3
48°00′ — 49°59′ N.	50.0	50.0	.0	.0	.0	.0	100.0	.0	.0	7.3	92.7	.0	.0		4	27	38
46°00′ — 47°59′ N.	42.9	57.1	.0	.0	.0	—	—	—	—	—	—	—	—		28	0	0
Total	43.9	56.2	.0	.0	.0	.0	100.0	.0	.0	9.1	90.9	.0	.0		32	27	41
Longline:																	
46°00′ — 47°59′ N.	—	—	—	—	—	5.3	94.7	.0	.0	—	—	—	—		0	19	—
44°00′ — 45°59′ N.	—	—	—	—	—	.0	100.0	.0	.0	—	—	—	—		0	1	—

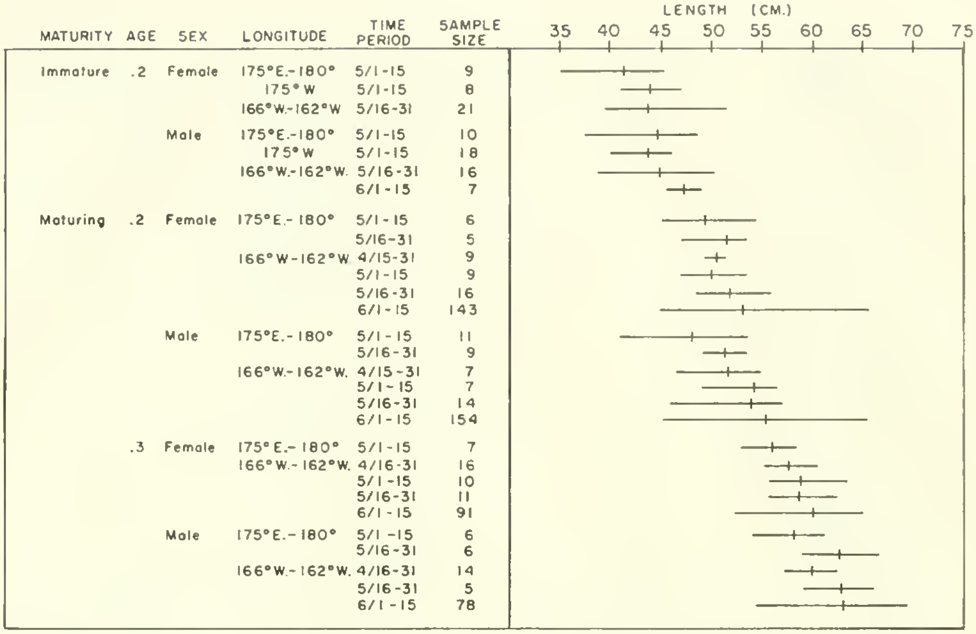

Figure 16.—Lengths (end of snout to fork of tail) of sockeye salmon taken in gill nets by Japanese and United States research vessels in April, May, and June 1968.

most of the samples prevents any detailed discussion of size. The data show, however, that immature sockeye salmon of ocean age .2 were about 35 to 51 cm. long in May and averaged about 44 cm. Maturing sockeye salmon of age .2 were about 41 to 65 cm. long and averaged about 50 to 55 cm. long. Mean lengths for age .3 maturing fish were 56 to 63 cm. Sockeye salmon taken south of the eastern Aleutian Islands tended to be slightly larger than those taken south of the western Aleutian Islands.

Chum Salmon

The age composition of maturing chum salmon, as in sockeye salmon, changed with latitude (table 3). From north to south age .3 fish increased in abundance, and age .4 fish decreased in abundance. Also, the age composition apparently changed from east to west when the total age composition from each cruise track was compared. Age .3 and .4 fish were almost equally represented in catches along long. 166° W. to 164° W., whereas age .3 fish became more abundant westward (55.2 percent along long. 175° W. and 74.0 percent along long. 175° E. to 180°).

The age composition of maturing fish changed somewhat from May to June in the area fished by the *George B. Kelez*:

Month	Number of fish	Age			
		.2	.3	.4	.5
May	183	0.6	47.9	51.5	0
June	314	8.5	67.2	23.8	0.4

The change resulted in a greater proportion of younger ages and the clear dominance of age .3 fish.

Longline catches by the *Wakashio Maru* and *Hokko Maru* also indicated a shift to younger ages from north to south. Longlines took a higher proportion of the older chum salmon than did gill nets.

Immature chum salmon were most abundant along long. 175° W. The *George B. Kelez* took only two immature fish in May and none in June along long. 166° W. and 164° W. The small sample taken on the westernmost cruise track indicated that most of the fish were age .2 and .3, whereas on long. 175° W. most were age .1 and .2.

The mean length of age .1 immature chum salmon, as shown by a small sample, was about 26 cm. (fig. 17). Immature age .2 fish had mean lengths of 41 to 42 cm., whereas the

Table 3.—Percentage age composition of immature and maturing chum salmon on the three cruise tracks—April and May 1968

Maturity gear and latitude	Age (winters at sea)												Sample size		
	175° E.-180°				175° W.				166° W.-164° W.				175° E.-180°	175° W.	166° W.-164° W.
	.1	.2	.3	.4	.1	.2	.3	.4	.1	.2	.3	.4			
	Percent				Percent				Percent				Number		
Maturing:															
Gill net:															
52°00′ — 53°59′ N.	—	—	—	—	—	—	—	—	0.0	0.0	7.9	92.1	—	—	40
50°00′ — 51°59′ N.	0.0	0.0	66.7	33.3	—	—	—	—	.0	.0	57.1	42.9	3	—	91
48°00′ — 49°59′ N.	.0	.0	66.7	33.3	0.0	0.0	40.0	60.0	.0	2.3	66.1	31.6	30	5	52
46°00′ — 47°59′ N.	.0	.0	77.4	22.6	.0	.0	88.9	11.1	—	—	—	—	31	9	—
44°00′ — 45°59′ N.	—	—	—	—	.0	66.7	33.3	.0	—	—	—	—	—	12	—
42°00′ — 43°59′ N.	.0	.0	87.5	12.5	.0	50.0	50.0	.0	—	—	—	—	8	4	—
40°00′ — 41°59′ N.	.0	.0	100.0	.0	—	—	—	—	—	—	—	—	1	—	—
Total	.0	.0	74.0	26.0	.0	34.5	55.2	10.3	.0	0.6	47.9	51.5	73	30	183
Longline:															
50°00′ — 51°59′ N.	.0	.0	38.5	61.5	.0	.0	64.5	35.5	—	—	—	—	13	30	—
48°00′ — 49°59′ N.	.0	.0	65.6	34.4	.0	.0	85.7	14.3	—	—	—	—	32	14	—
46°00′ — 47°59′ N.	—	—	—	—	—	.0	100.0	.0	—	—	—	—	—	2	—
44°00′ — 45°59′ N.	.0	100.0	.0	.0	.0	53.3	46.7	.0	—	—	—	—	1	15	—
Total	.0	2.1	56.5	41.3	.0	12.9	66.1	21.0	—	—	—	—	46	62	—
Immature:															
Gill net:															
48°00′ — 49°59′ N.	.0	.0	100.0	.0	—	—	—	—	—	—	—	—	1	—	—
46°00′ — 47°59′ N.	12.5	37.5	50.0	.0	—	—	—	—	—	—	—	—	8	—	—
44°00′ — 45°59′ N.	—	—	—	—	38.9	47.2	13.9	.0	—	—	—	—	—	36	—
42°00′ — 43°59′ N.	.0	50.0	.0	50.0	25.0	75.0	.0	.0	—	—	—	—	2	4	—
Total	9.1	36.4	45.5	9.1	37.5	50.0	12.5	.0	—	—	—	—	11	40	—

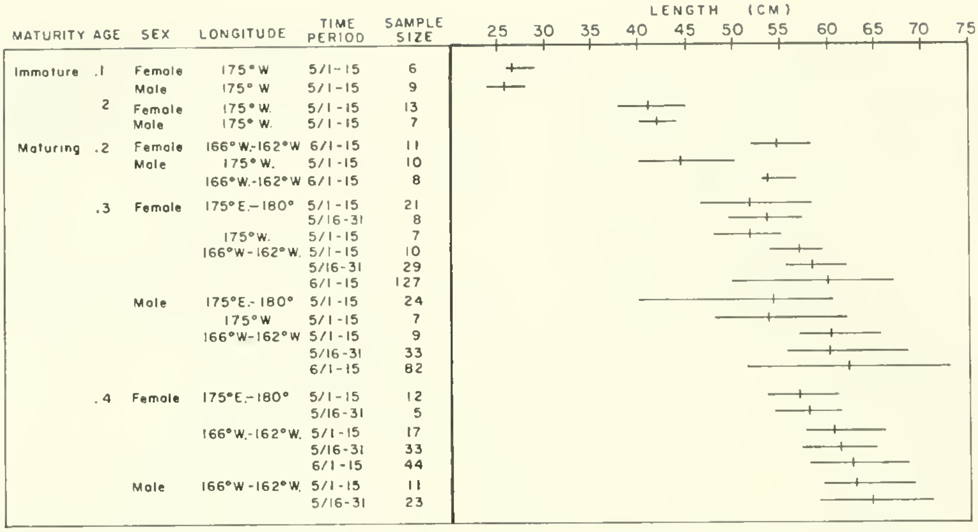

Figure 17.—Lengths (end of snout to fork of tail) of chum salmon taken in gill nets by Japanese and United States research vessels in May and June 1968.

maturing age .2 fish were about 45 to 54 cm. long. Mean lengths for maturing age .3 chum salmon were about 52 to 62 cm. and for age .4 fish about 57 to 65 cm. Similar to sockeye salmon, chum salmon taken south of the eastern Aleutian Islands were usually larger for a given age, sex, and time period than those taken south of the central and western Aleutian Islands.

Pink Salmon

Body lengths of pink salmon taken by gill nets varied from 31 to 59 cm.; mean lengths of gill net catches varied from about 40 to 45 cm. (fig. 18). The increase in size from west to east that was noted for sockeye and chum salmon was not evident for pink salmon. Pink salmon on the cruise track at long. 175° W. were smaller than those on the other two cruise tracks.

DISTRIBUTION OF LARVAL FISH

Sampling of larval fish by the Japanese research vessels at each salmon fishing station show varying distributions of groups (fig. 19). *Hemilepidotus* were the most abundant larvae and were found only north of lat. 47° N. *Bathymaster* larvae had a similar distribution but were less abundant. Most of the Myctophidae larvae were south of lat. 48° N. and therefore primarily south of the larvae of *Hemilepidotus* and *Bathymaster*. Hexagrammidae

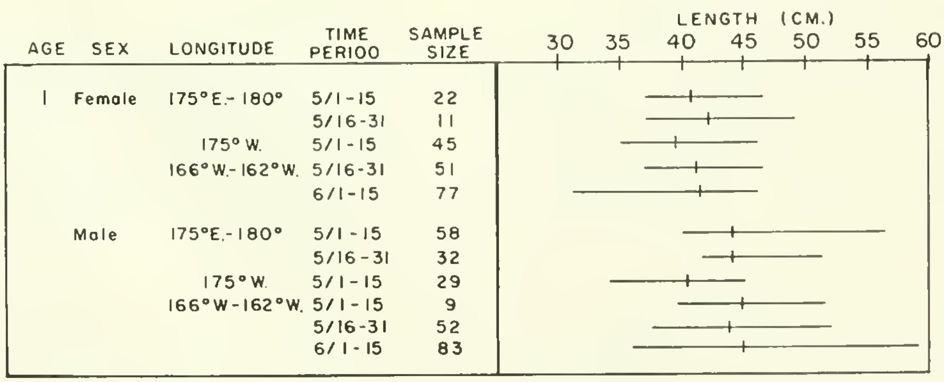

Figure 18.—Lengths (end of snout to fork of tail) of pink salmon taken in gill nets by Japanese and United States research vessels in May and June 1968.

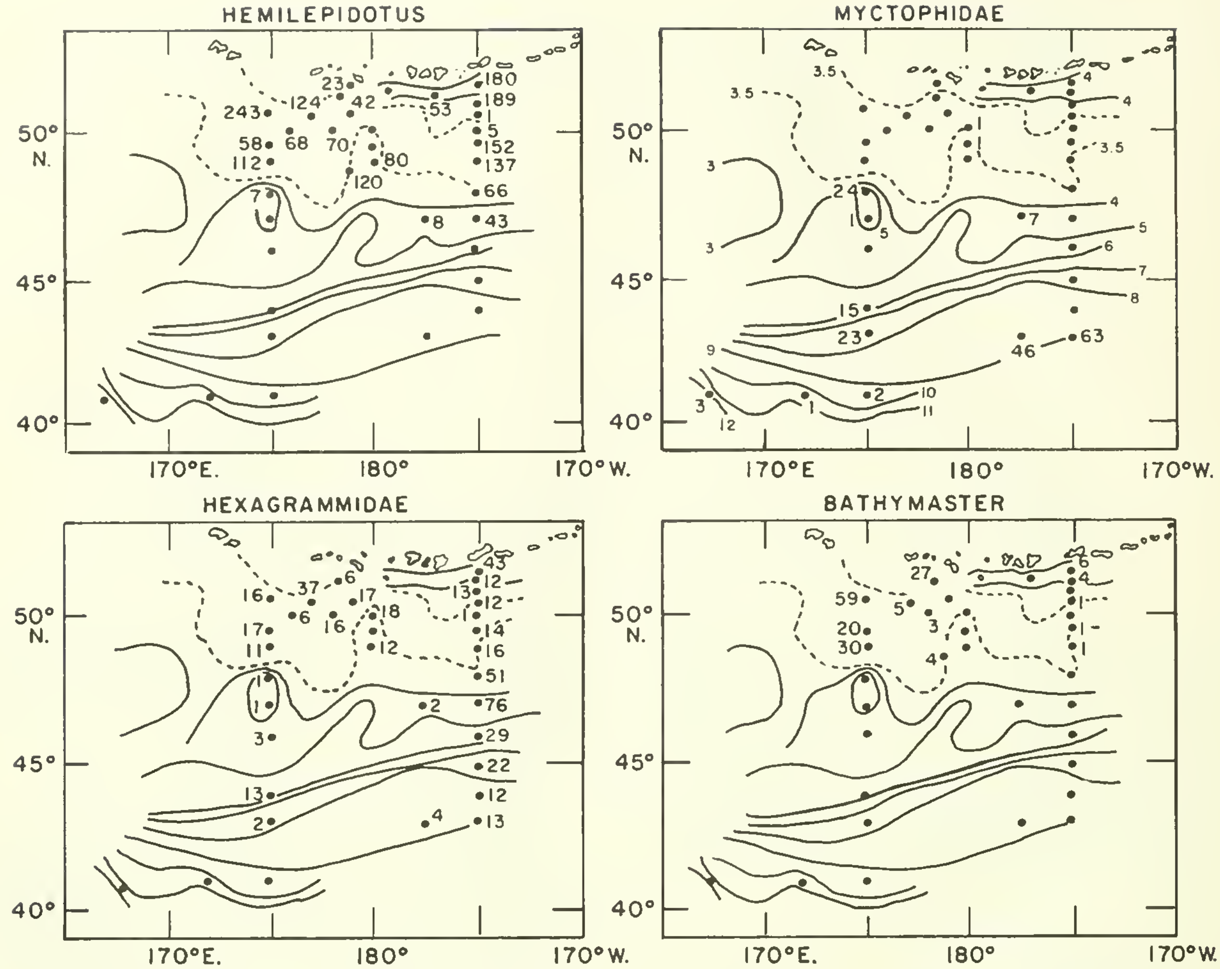

Figure 19.—Larval fish distribution and isotherms (° C.) at 100-m. depth in April and May 1968.

were taken throughout most of the area sampled except in the extreme southern part near lat. 41° N.

The distributions of *Hemilepidotus* and *Bathymaster* most closely resembled that of sockeye salmon. Myctophidae larvae were generally south of most sockeye salmon but were in areas corresponding to the southern part of the chum and pink salmon distribution. The larval Hexagrammidae were distributed over all areas in which salmon were found.

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